X. *Aſtronomical Obſervations on the Rotation of the Planets round their Axes, made with a View to determine whether the Earth's diurnal Motion is perfectly equable. In a Letter from Mr.* William Herſchel *of* Bath *to* William Watſon, *M. D. F. R. S.*

Read January 11, 1781.

S I R, Bath, October 18, 1780.

THE various motions of the planet we inhabit; the annual revolution in its orbit; the diurnal rotation round its axis; the menſtrual motion round the common center of gravity of the moon and earth; the preceſſion of the equinoctial points; the diminution of the obliquity of the ecliptic; the nutation of the earth's axis: in ſhort, every one of the motions that ariſe from the actions of the ſun, moon, and planets, combined with the ſpheroidical figure of the earth, and the projectile and rotatory motions firſt impreſſed upon it, have all been conſidered by aſtronomers, and their real and apparent inequalities inveſtigated. And to the great honour of modern aſtronomers it muſt be confeſſed, that no ſcience has ever made ſuch conſiderable ſtrides towards perfection in ſo ſhort a time as aſtronomy has done ſince the invention of the teleſcope.

There is one of the motions of the earth however which, it ſeems, has hitherto eſcaped the ſcrutiny of obſervers; I mean the diurnal rotation round its axis. The principal reaſon why this has not been looked into, is probably the difficulty of finding a proper ſtandard to meaſure it by; ſince it is itſelf uſed as the ſtandard by which we meaſure all the other motions. We have, indeed, no cauſe to ſuſpect any very material periodical irregularity, either diurnal, menſtrual, or annual; for the great perfection of our preſent time-pieces would have diſcovered any conſiderable deviation from that equability which we have hitherto aſcribed to the diurnal motion of the earth. And yet, it is not perhaps altogether impoſſible but that inequalities may exiſt in this motion which, in an age where obſervations are carried to ſuch a degree of refinement, may be of ſome conſequence.

To ſhew how far time-keepers, though ever ſo perfect, are from being a proper, or at leaſt a ſufficient, ſtandard to examine the diurnal motion of the earth by, I may aſk, whether it is probable, that any clock would have diſcovered to us the aberration of the fixed ſtars? And yet that aberration produces a change in longitude, and of conſequence in right aſcenſion, which cauſes an annual irregularity in a ſtar's coming to the meridian, which a time-piece, were it a ſufficient ſtandard, would ſoon have diſcovered, and which we might have attributed to an inequality of the earth's diurnal motion, had we not been acquainted with its real cauſe. And if we were to find out any apparent irregularity, acceleration, or retardation, ſhould we not much rather ſuſpect the clock than the diurnal motion? I may therefore venture to ſay, that the aberration of the fixed ſtars, though attended with the above mentioned conſequence, would for ever have remained a ſecret to us, if it had not been found out by other methods than time-keepers.

Now, if time-pieces do fail us in this critical caſe, where we ſtand in the greateſt need of their aſſiſtance, it is almoſt in vain to expect any help from another quarter; for what mechanical movement on earth, or motion of the heavens, is there that can meaſure out ſuch equal portions of time as we require to compare the diurnal motion of the earth to? However, to proceed, ſince we have already great proofs that the diurnal motion of the earth is, if not perfectly equable, at leaſt more ſo than any other motion we are acquainted with, it will not appear abſurd to ſuppoſe the diurnal rotation of the other planets to be ſo likewiſe. This ſuggeſted to me the thoughts of eſtimating the diurnal motion of one planet very exactly by that of another, making each the ſtandard of the other. In this manner we may obtain a comparative view, by which future aſtronomers, if they ſhall hereafter be inclined to purſue the ſubject, may be enabled to make ſome eſtimate of the general equability of the rotatory motions of the planets. For if in length of time they ſhould perceive ſome ſmall retardation in the diurnal motion of a planet occaſioned by ſome reſiſtance of a very ſubtle medium in which the heavenly bodies perhaps move; or, on the other hand, if there ſhould be found an acceleration from ſome cauſe or other, they might then aſcribe the alteration either to the diurnal motion of the earth, or to the gyration of the other planet, according as circumſtances, or obſerved phænomena, ſhould make one or the other of theſe opinions moſt probable.

Now, this method of comparing together different rotations of ſeveral planets, ſimple as it may appear, was not without ſome difficulties. In the firſt place it was evident, that the common account of their diurnal motions *, which makes that

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* Venus ſpatio 23 horarum gyrationem circa axem ab occidente in orientem perficit. Mars ſimilem rotationem, horis 24 min. 40 abſolvit. Macularum revolutionibus ſæpius obſervatis, Ds. CASSINI comperuit periodum Jovis circa proprium Axem eſſe horarum 9, minutorum 56. KEILL, Aſt. Lect. V.

of Jupiter 9 h. 56′, of Mars 24 h. 40′, how true ſoever it may be in a general way, was much too inaccurate for this critical purpoſe. The gyration of Venus was ſtill leſs to be depended upon, being only noted to the hour without the minutes: it became, therefore, neceſſary to proceed to obſervations of a more determinate kind. From what I had already ſeen of the rotation of the planets, I concluded, that Mars on ſeveral accounts would be the moſt eligible planet for my purpoſe: for the ſpots on Jupiter change ſo often that it is not eaſy, if at all poſſible, to aſcertain the identity of the ſame appearance, for any conſiderable length of time. Nor do the dark ſpots only change their place, which may be ſuppoſed to be large black congeries of vapours and clouds ſwimming in the atmoſphere of Jupiter; but alſo the bright ſpots, though they may adhere firmly to the body of Jupiter, may undergo ſome apparent change of ſituation by being differently covered or uncovered on one ſide or the other, by alterations in the belts. It will be ſeen hereafter, that I have obſerved the revolution of a very bright ſpot, not ſuſpected of any change of ſituation, to be firſt, by one ſet of obſervations, at the rate of 9 h. 51′ 45″,6; and afterwards, by another ſet immediately following at the rate of 9 h. 50′ 48″.

As the principal belts on Jupiter are equatorial, and as we have certain conſtant winds upon our planet, eſpecially near the equator, that regularly, for certain periods, blow the ſame way *, it is eaſily ſuppoſed, that they may form equatorial belts by gathering together the vapours which ſwim in our atmoſphere, and carrying them about in the ſame direction. This will, by analogy, account for all the irregularities of Jupiter's

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* See Acta Eruditorum, 1687. Dr. HALLEY's Account of periodical Winds.

piter's revolutions, deduced from ſpots on his diſk that may have changed their ſituation; for if we ſuppoſe the rotation of Jupiter, according to CASSINI, to be 9 h. 56′, then ſome ſpots that I have obſerved muſt have been carried through about 60° of Jupiter's equator in 22 of his revolutions or days. This would certainly be a very great velocity in the clouds, which is, however, not unparalleled by what has happened in our own atmoſphere.

But to return to my purpoſe: on the planet Mars we ſee ſpots of a different nature; their conſtant and determined ſhape, as well as remarkable colour, ſhew them to be permanent and faſtened the body of the planet. Theſe will give the revolution of his equator to a great certainty, and by a great number of revolutions, to a very great exactneſs alſo. Suppoſing then, that, by a method I ſhall hereafter deſcribe, we can determine whether a ſpot on the diſk of Mars is, or is not, in the line which joins the center of the earth and the center of that planet, to half an hour's time with certainty (I believe ten or twelve minutes will be found ſufficient for that purpoſe), in this caſe we ſhall in 30 days have the revolution true to a minute; and, by continuing theſe obſervations for three months, we ſhall have it to 20″. When we are ſo far certain, we can eaſily arrive to a much greater degree of exactneſs; for as we now can no longer miſtake a whole revolution, if we take the time of any particular ſpot's being in the line which joins the centers of the planets during one oppoſition of Mars, and take the ſame again at or near the next oppoſition, we ſhall have an interval of about 780 days, which will give the diurnal motion of that planet true to about 2″. The next oppoſition will give it to one, and ſo forth; by which means, and by taking a proper number of ſuch periods, we may determine the rotation of

Mars to as great an exactneſs as we ſhall think neceſſary for the purpoſe of our comparative view.

Had ſuch obſervations as theſe been made two thouſand, or perhaps only ſo many hundred years ago, we might now, by repeating them, moſt probably become acquainted with ſome curious minute changes of the ſolar ſyſtem that have hitherto paſſed unnoticed.

There is a certain circumſtance which would almoſt create a ſuſpicion that there has been ſome retardation in the diurnal motion of the earth. The difference between the equatorial and polar diameters of the earth, by actual meaſurement has been found to be about 36 Engliſh miles and 9 tenths; but by a calculation wherein the preſent rotation is made uſe of it will only amount to about 33 miles and 8 tenths: from which it ſhould ſeem probable, that when the earth aſſumed the preſent form, the diurnal rotation was ſomewhat quicker than it is at preſent, by which means the centrifugal force bore a greater proportion to the force of gravity to which it is contrary, and thus occaſioned a higher elevation of the equatorial parts. But I would not lay much ſtreſs upon this argument; for, in the calculation, it has been ſuppoſed, that the earth is nearly of an equal denſity at the ſurface and towards the center, which it ſeems is not agreeable to ſome late curious experiments and calculations that have been made under the conduct of the Aſtronomer Royal upon the attraction of a mountain *, the reſult of which ought now to be taken into conſideration, and the calculation repeated. If all the *data* could be exactly depended upon, it would be practicable enough from the laws of gravity, and the preſent rotation and given form of the earth, to find the centrifugal force required to produce that form, and thence to ſhew what muſt have been its diurnal motion when it aſſumed the ſame. However, theſe are reſearches that in my preſent ſituation I neither have opportunity nor perhaps ability enough to inveſtigate properly; and which, therefore, I hope ſome of our excellent mathematicians will think worth while to look into.

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* See Mr. HUTTON's Account of the Calculations made from the Survey and Meaſures taken at Schehallien, in order to aſcertain the mean Denſity of the Earth. Phil. Tranſ. 1778.

I ſhall now relate my obſervations on Jupiter and Mars. The teleſcopes I uſed are of my own conſtruction; and are, a twenty-feet Newtonian reflector, a ten-feet reflector of the ſame form, and a ſeven-feet reflector already mentioned in my paper on the mountains of the moon. My time I gained by equal altitudes taken with a braſs quadrant of two-feet radius, carrying a teleſcope which magnifies about 40 times; for the correction of altitudes taken of the ſun I uſed DE LA LANDE's tables. I kept my time by two very good pieces; one having a deal pendulum-rod, the other a compounded one of braſs and iron, both having a proper contrivance not to ſtop when winding up. The rate of going of my clocks I determined by the tranſit of ſtars.

Obſervations on Jupiter in the year 1778.

February 24. Clock 1′ 10″ too ſoon. About 9 o'clock I ſaw a bright belt on one part of the diſk of Jupiter, ſee tab. V. fig. 1.

About 10 o'clock it was advanced as far as the center, fig. 2.

11 h. The white belt ſtill more advanced, fig. 3.

11 h. 25′. It approached towards the edge of the diſk; and at 12 h. was extended all over, as in fig. 4.

February 25. 8 h. The ſame bright belt I obſerved yeſterday extends all over.

8 h. 45′. It is divided by a darkiſh ſpot, ſituated at ſome diſtance from the center, as in fig. 5.

9 h. 5′. The ſmall dark diviſion is advanced a little farther than the center, as in fig. 6..

9 h. 23′. The ſpot is viſibly advanced a conſiderable deal farther.

March 2. 8 h. 2′. The darkiſh ſpot, with ſome alteration in its ſhape, is now in the middle of the diſk, ſee fig. 7.

March 3. 10 h. 34′. The bright belt on the ſouth of the equator is now in the middle; that is to ſay, if a line be drawn perpendicular to the equatorial belt, and through the center, the end of the equatorial belt now touches it, fig. 8.

13 h. 49′. The darkiſh ſpot, in which there has been ſome alteration ſince yeſterday, ſeems now to be in the center, fig. 9.

March 14. The clock altered to true equated time; but the rate of going not changed, being well regulated.

7 h. 35′. The ſpot is now in the center, but does not ſeem quite to fill the white belt; nor is it ſo large and diſtinct as it was before, fig. 10.

April 7. 9 h. 31′. There are three dark ſpots in the equatorial belt nearly in the center, ſee fig. 11.

April 12. 7 h. 50′. The three dark ſpots are in the center. The ſourthernmoſt of the three is nearly quite vaniſhed; the other two are alſo much fainter. They are, however, diſtinct enough to be known, fig. 12.

Obſervations on Jupiter in 1779.

April 14. Clock 52″ too late. 8 h. 48′ A remarkable bright ſpot in the equatorial belt towards the north is in the center, ſee fig. 18.

8 h. 58′. The ſpot is a little paſt the center.

April 19. Clock true mean time. 7 h. 10′. There is a bright ſpot juſt now in the center, which, from its ſhape, I take to be the ſame that was there April 14th.

7 h. 20′. The ſpot is viſibly paſt the center.

April 23. Clock ſhews true time. 9 h. 38′. The ſame bright ſpot is in the center.

9 h. 43′. It is paſt the center. *Memorandum*, my timepiece may be depended upon to a few ſeconds.

It will not be amiſs to obſerve, that the ſpots, as well as a great many other phænomena, were watched as they came on, paſſed over the center, and went off the diſk of Jupiter; but I have only ſelected thoſe obſervations that were neceſſary to my preſent purpoſe.

Comparing together the obſervations that were made in the year 1778, February 24th and March 3d, we obtain an interval of 7 days 34 minutes, which being divided by 17 revolutions made by Jupiter on his axis, we have the time of one ſynodical revolution equal to 9 h. 54′ 56″,4.

The dark ſpot on February 25 was obſerved ſome time before, and alſo juſt after it was paſt the center; therefore I have ſuppoſed it to be in the center about 8 h. 58′: and we have,

	D.	H.	M.
February	25	8	58
March	2	8	2
Divided by 12 rev.	4	23	4

1 revolution = 9 h. 55′ 20″

February	25	8	58
March	3	13	49
15 revol.	6	4	51

1 revolution = 9 h. 55′ 24″.

February	25	8	58	0	
March	14	7	36	10	allowing 1′ 10″ for the alt. of the clock.
41 revol.	16	22	38	10	

1 revolution = 9 h. 55′ 4″,6.

March	2	8	2
	3	13	49
1 revol.	1	5	47

1 revolution = 9 h. 55′ 40″.

March	2	8	2	0
	14	7	36	10
29 revol.	11	23	34	10

1 revolution = 9 h. 54′ 58″,2.

	D.	H.	M.	S.
March	3	13	49	0
	14	7	36	10
Divided by 26 rev.	10	17	47	10

1 revolution = 9 h. 54′ 53″,4.

April	7	9	31
	12	7	50
12 revol.	4	22	29

1 revolution = 9 h. 51′ 35″.

Again, comparing together the obſervations of 1779, which were made with the utmoſt attention to time, we have,

April	14	8	48	52
April	19	7	10	0
12 revol.	4	22	21	8

1 revolution = 9 h. 51′ 45″6.

April	19	7	10
April	23	9	38
10 revol.	4	2	28

1 revolution = 9 h. 50′ 48″.

And taking both together,

April	14	8	48	52
April	23	9	38	0
22 revol.	9	0	49	8

1 revolution = 9 h, 51′ 19″,4.

Theſe ſeveral reſults are ſo exceedingly various, that it is evident Jupiter is not a proper planet for the critical purpoſe of a comparative view of the diurnal motions; nor can this great variety proceed from any inaccuracy in the obſervations: for, in my opinion, it is not well poſſible to make a miſtake in the ſituation of a ſpot that ſhall amount to ſo much as five minutes of time. The obſervation of April 23, 1779, was made with a view to aſcertain this point, when it was found that five minutes of time made a ſenſible difference in the ſituation of a ſpot when near the center.

If we reduce the ſynodical revolutions to ſydereal ones, the reſult will be ſo little different from the above, that I have not thought it worth while to do it in this place. By a compariſon of the different periods it appears, that a ſpot which is carried about in the atmoſphere of Jupiter generally ſuffers an acceleration, or, which is the ſame thing, performs its revolutions by degrees in leſs time than it did at firſt; for the ſpot obſerved in 1778 moved at the following rates. From February 25. to March 2. in 9 h. 55′ 20″; to March 3. nearly the ſame; to March 14. in 9 h. 55′ 4″; from March 2. to March 3. in 9 h. 55′ 40″; to March 14. in 9 h. 54′ 58″; from March 3. to March 14. in 9 h. 54′ 53″. In 1779 a ſpot moved from April 14. to April 19. at the rate of 9 h. 51′ 45″; to April 23. in 9 h. 51′ 24″; and from April 19. to April 24. in 9 h. 50′ 48″; all which is agreeable enough to the theory of equatorial winds, ſince it may probably take up ſometime before a ſpot can acquire a ſufficient velocity to go as faſt as thoſe winds may blow. And, by the by, if Jupiter's ſpots ſhould be obſerved in different parts of his year, and be found in ſome to be accelerated, in others to be retarded, it would almoſt amount to a demonſtration of his monſoons and their periodical changes; but if his axis ſhould not be inclined enough to his orbit, to occaſion ſuch a change, they may probably always blow in the ſame direction.

Obſervations on Mars in the year 1777.

Twenty-feet Newtonian reflector; power 300.

April 8. 7 h. 30′. I obſerved two ſpots upon Mars, with a bright belt or partition between them. The belt was not very well defined, ſee tab. VI. fig. 14.

9 h. 30′. The ſpots are advanced, and more ſpotted parts are viſible, fig. 15.

10 h. The revolution of Mars on his axis is now very evident, fig. 16.

April 17. Ten-feet Newtonian reflector; power about 211. 7 h. 50′. Mars appeared as in fig. 17. At *a* and *b* there were two bright ſpots, ſo luminous that they ſeemed to project beyond the diſk. At *c* and *d* there were two very dark ſpots, joined by a leſſer black line in the middle, which however was croſſed at *e* and *f* by a very faint whitiſh partition.

April 26. Ten-feet reflector; power 211.

9 h. 5′. The ſpots on the planet are very faint, and much about as in fig. 18.

April 27. Ten-feet reflector; power 324.

8 h. 40′. The evening very fine: my teleſcope in compleat order. The ſpots as in fig. 19.

Obſervations on Mars in the year 1779.

May 9th. Clock 15″ too faſt; by equal altitudes on the 14th of April, and by the tranſit of a ſtar, is found to loſe 1″,45 *per* day.

11 h. 1′ by the clock, I found the ſituation of the ſpots on Mars as in figure 20; there is a very remarkable dark ſpot not far from the center.

11 h. 30′. The figures are gone from the center.

May 11. Clock 12″ too faſt.

10 h. 18′. The ſame ſpot that was viſible May 9. is on the diſk, the darkeſt place being intirely ſouth-eaſt of the center, ſee fig. 21.

11 h. 43′. The darkeſt part is almoſt arrived at the center, fig. 22.

12 h. 17′. The dark ſpot is with its edge juſt near the center, as in fig. 23.

May 13. Seven-feet reflector; power 222. Clock 9″ too faſt.

11 h. 26′. Mars ſeems now to be in the ſame ſituation he was the 11th, at 10 h. 8′.

May 22. Clock 4″ too ſlow.

12 h. 5′. The figure of May 11th is not on the diſk; but ſome other fainter ſpots are viſible. The air is full of vapours.

June 6. The clock ſet by ten equal altitudes taken to-day, and by the tranſit of δ Scorpii loſes 1″,9 *per* day. What I have perhaps improperly called a tranſit is the occultation of a ſtar paſſing behind the perpendicular edge of a high building at about 40 yards diſtance, obſerved with a fixed teleſcope directed to the place where it vaniſhes.

10 h. 10′. The ſame figure is upon the diſk of Mars which was there April 8, 1777, at 7 h. 30′.

June 15. Clock 17″ too ſlow. 9 h. 45′. The ſame figure is upon Mars that was there May 9. at 11 h. 1′; but it is more advanced. I ſuppoſe it to be the ſame, and in the ſame ſituation, as April 17, 1777, at 7 h. 50′.

June 17. Clock 20″ ſlow.

9 h. 12′. The dark ſpot on Mars is rather more advanced than it was May 11th, at 10 h. 18′.

10 h. The ſpot is viſibly advanced: I ſuppoſe it will take near an hour to come to the center.

10 h. 15′. A very thick fog obſcures the ſky.

11 h. 15′. The ſame darkneſs.

June 19. Clock 22″ too ſlow by the tranſit of δ Scorpii obſerved this evening.

8 h. 40′. The figure on the diſk of Mars appears now to be as it was April 26, 1777, at 9 h. 5′, ſee fig. 18.

11 h. 30′. The figure of May 11. which I have been hitherto watching, is not come to the poſition it was then at 11 h. 43′, but cannot be far from it. I fear, as Mars approaches the horizon, I ſhall not be able to follow him till the figure comes to the center.

11 h. 47′. The ſtate of the air near the horizon is very unfavourable. With much difficulty I can but juſt ſee that the figure is not quite ſo far advanced as it was May 11th, at 11 h. 43′, but can certainly not be above two or three minutes from it.

11 h. 51′. The undulation of the air prevents all further obſervation.

Let us now examine the reſult of the above mentioned obſervations: comparing together the two following ſhort intervals of the year 1779, we have,

	D.	H.	M.	S.
From May	9	11	0	45
to May	11	12	16	48
Divided by 2 revol.	2	1	16	3

Gives 1 revolution = 24 h. 38′ 1″,5.

A ſecond ſmall interval.

May	11	10	17	48
	13	11	25	51
2 revol.	2	1	8	3

1 revolution = 24 h. 34′ 1″,5.

Here we have two very ſhort intervals that agree to 4′, which is more than we could have expected in ſuch ſhort periods of time.

Comparing together obſervations that were made at a greater diſtance, we find,

Firſt monthly period,

May	11	10	17	48	
June	17	9	9	20	allowing 3′ becauſe the obſ. ſays the ſpot was rather more advanced.
36 revol.	36	22	51	32	

1 revolution = 24 h. 38′ 5″,9.

Second monthly period,

May	11	11	42	48	
June	19	11	50	22	allowing 3′ for the time the ſpot would have taken to come to the place mentioned.
38 revol.	39	0	7	34	

1 revolution = 24 h. 38′ 5″,4.

Third monthly period,

	D.	H.	M.	S.
May	13	11	25	51
June	17	9	9	20
34 revol.	34	21	43	29

1 revolution = 24 h. 38′ 20″,3

This laſt is, perhaps, as likely to be near the truth as any, ſince the ſame ſpot was here obſerved for the third time, and therefore its motion become more familiar.

Here we have three longer periods that agree to fifteen ſeconds, which is quite ſufficient for extending the interval of time to thoſe obſervations that were made in the year 1777. But as theſe are the ſynodical revolutions, it will be neceſſary firſt to reduce them to ſydereal rotations.

In figure 24. let us ſuppoſe the orbit of Mars, MABC, to be in the ſame plane with the orbit of the earth, EDFG; and the axis of Mars to be perpendicular to his orbit. Let M, E, *m*, *e*, be the ſituations of Mars and the earth on the 13th of May and 17th of June; then will the line EM, that connects the centers of Mars and the earth, point out the geocentric place of Mars on the 13th of May; and the line *em*, the geocentric place of the ſame planet on the 17th of June. Draw *er* and *ms* parallel to ER; then will *er* point out the geocentric place of Mars on the 13th of May; and the angle *sme* is equal to the angle *mer*. Now, by an ephemeris * the geocentric place of Mars, May 13. at 11 h. 26′ was 7 ſ. 20 d. 59′ 21″;

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* The Nautical Almanac gives the geocentric place of Mars only to every ſixth day; for which reaſon I uſed WHITE's Ephemeris, where it is given for every day, though perhaps not with ſo much exactneſs as I could wiſh.

and on the 17th of June, at 9 h. 9′, it was 7 ſ. 12 d. 27′ 22″, by which we obtain the difference or angle *rem* = *ems* = 8 d. 31′ 59″.

Now a ſpot on Mars, ſituated in the direction ME, will have made a ſydereal revolution when it returns to the ſame, or a parallel direction *ms*. From which we gather, that the ſpot on the 17th of June, after coming to the line *me*, where it finiſhes the ſynodical revolution, will have to go through an arch of 8 d. 31′. 59″, in order to arrive into the direction of the line *ms*, where it finiſhes the ſydereal rotation. The time it will take to go through this arch, at the ſydereal rate of 24 h. 39′ 20″ to 360 degrees, or 4″,109 *per* minute of a degree, will be 35′ 3″,8; this being divided by the numbers of revolution 34, gives 1′ 1″,8; which, added to 24 h. 38′ 20″,3, gives us 24 h. 39′ 22″,1 for the ſydereal revolution of Mars, as found by the third of the monthly periods. This quantity will help us to find a proper diviſor for the three following long biennial periods.

It is to be obſerved, that Mars has been retrograde in the above example, for which reaſon the meaſure of the angle *ems* was to be added to the ſynodical revolution when we wanted to find the ſydereal rotation; but if he had been direct, or if his place had been more advanced in the ecliptic than that to which we compared it, as at μ, then the line $\mu\sigma$ parallel to EM would be the direction to which the ſpot ſhould return, in order to accompliſh a ſydereal revolution, and therefore the quantity of the angle $\sigma\mu e = \mu er$, or difference of the geocentric places ought to be ſubtracted from the ſynodical revolution to obtain the ſydereal one.

Firſt

		D.	M.	S.
Firſt biennial period,	1777, April	8	7	30
	1779, June	6	10	10
		789	2	40

The geocentric places of Mars at thoſe times were,

S.	D.	′	″
6	6	31	26
7	13	48	30
1	7	17	4

turned into time at 4″,109 *per* minute of a degree and ſubtracted, becauſe Mars is more advanced in the ecliptic, is

	789	2	40	0
	—	2	33	11,8
Divided by 768 rev.	789	0	6	48,2

1 revolution = 24 h. 39′ 23″,03.

		D.	H.	M.	S.
Second biennial period,	1777, April	17	7	50	0
	1779, June	15	9	45	17
		789	1	55	17

	S.	D.	′	″
Geocentric places	6	3	31	27
	7	12	40	23
	1	9	8	56

Turned into time and ſubtracted	789	1	55	17
	—	2	40	52
768 revol.	788	23	14	25

1 revolution = 24 h. 39′ 18,″94.

Third

		D.	H.	M.	S.
Third biennial period,	1777, April	26	9	5	0
	1779, June	19	8	40	22
		783	23	35	22

	S.	D.	′	″
Geocentric places	6	1	24	36
	7	12	31	48
	1	11	7	12

Turned into time	783	23	35	22
and ſubtracted	—	2	45	15,6
763 revol.	783	20	50	6,4

1 revolution = 24 h. 39′ 23″,04.

As theſe three periods are ſupported by obſervations of equal validity, I ſhall take a mean of them all for the neareſt approximation to the true ſydereal revolution of Mars on his axis, which therefore is 24 h. 39′ 21″,67.

It remains now only to ſee how far we may depend upon this determination of Mars's diurnal rotation as coming near the truth; and looking over thoſe cauſes which may poſſibly produce any errors, we find, firſt of all, that in the long biennial periods a miſtake in the number of revolutions would produce a conſiderable deviation from truth. Secondly, in the obſervations of a ſpot which moves ſo ſlow, we are alſo liable to ſome conſiderable miſtake in eſtimating the time when it comes to a certain place; and the more ſo, if that place is not the center. Laſtly, the time itſelf is liable to inaccuracy.

As to the firſt, it appears from the three monthly periods obſerved in the year 1779, when the proper allowances for the geocentric places are made, that the ſydereal revolution of Mars cannot well be leſs than 24 h. 39′ 5″, nor more than 24 h. 39′ 22″; but if we ſhould divide any one of the three biennial periods by a ſuppoſed number of revolutions, only one more or one leſs than we have done, the difference would be ſo conſiderable, that nothing but a miſtake in every one of the three monthly periods, of at leaſt one whole hour, could juſtify ſuch a ſuppoſition; and that ſuch a miſtake in the ſituation of a ſpot on Mars cannot have been made in thoſe obſervations, I think, is evident enough from the exactneſs with which they were made, and from their agreement with each other.

The ſecond cauſe of error, which is the uncertainty in aſſigning the exact time when a ſpot comes to the center, is of ſome force. But it ſeems to me highly probable, from the manner in which I have ſeen the ſpots on Mars paſs over the diſk of that planet, that there can hardly be ſo great an error as 10′ in an obſervation of any remarkable ſpot's coming to the center. However, not being willing to truſt more to the eye than I ought to do, I had recourſe to the following experiment. I drew ſeveral circles of one inch radius, taking care to make no viſible impreſſion of a center; and placed in each a fine point at the ſeveral diſtances of .0424, .0636, .0848, in ten thouſands of an inch from the real center; ſome to the right, others to the left. Theſe meaſures are the ſines to radius one, of 2° 26′, 3° 39′, and 4° 52′, which are the arches a ſpot on Mars paſſes over in 10, 15, 20′ minutes reſpectively. I expoſed them to ſeveral perſons unacquainted with my deſigns, and found, that not one of them made a ſingle miſtake in ſaying whether the point was, or was not, in the center of the circle, and which way it deviated from it. As the direction of the motion of a ſpot on Mars is known, I thought the perſons who were to judge of the place of the points were intitled to be acquainted with the line in which they were placed, which for that reaſon was always to the right and left only. The points that anſwer to the excentricity of 15 and 20′ are indeed ſo viſibly out of the center, that I believe we may ſafely ſay, that any miſtake, in eſtimating the time of a ſpot on Mars coming to the center, cannot well exceed a quarter of an hour at the outſide.

As for the third and laſt occaſion of error, the time itſelf, I believe my manner of obtaining and keeping it in the year 1779 will appear ſatisfactory, and may, I think, be depended upon to a few ſeconds; but the obſervations of the year 1777, indeed, are far from having the ſame advantage. I was not then provided with an altitude inſtrument, therefore ſet my clock by a good ſun-dial, with the equation of time contained in the Nautical Almanac, and found it to agree generally to a minute or two with the time calculated for the eclipſes of Jupiter's firſt ſatellite, as I deduced it for Bath from the Nautical Almanac. However, it was certainly liable to an error of ſeveral minutes; therefore, allowing no leſs than 10′ for the clock in 1777, and 20′ for an error in eſtimating the ſituation of a ſpot in 1779, it will both amount to half an hour: then, if we take a mean of the three numbers, whereby we have divided the three biennial periods, we have $766\frac{1}{3}$; and half an hour, divided by $766\frac{1}{3}$, will therefore give us the quantity to which, it ſeems, can amount, all the uncertainty in the ſydereal diurnal rotation of Mars, which is 2″,34.

A nearer approximation to truth I hope to obtain at the next oppoſition, which will happen about the middle of July 1781.

I have ventured to calculate the times for that oppoſition, when the edge of the remarkable dark ſpot will be ſeen near the center, as it is in figure 23, or, which is the ſame thing, as it was the 11th of May 1779, at 12 h. 17′. The ſpot not being viſible at the time of the oppoſition, I have taken the neareſt period, before and after, in which it will paſs over the diſk. There is, however, a circumſtance which may make the appearance of the ſpot not quite ſimilar to the figure I have drawn, even though the rotations ſhould perfectly anſwer as to the times; for the poſition of the axis of Mars being ſtill in ſome meaſure unknown, I could make no allowance for a change, which a difference in the ſituation of no leſs than two ſigns may occaſion, though in all probability it will not be very conſiderable.

Thoſe who are provided with proper teleſcopes will have an opportunity to ſee how far the calculated times agree with the ſpot's appearance; and it is by this means I alſo hope to correct and improve the tables I have drawn up for this purpoſe, and further to approximate to a true theory of the gyration of this planet.

Not knowing the exact difference of meridians between Greenwich and this place, I have calculated the ſpot's appearance for the meridian of Bath. From an eclipſe or two of Jupiter's ſatellites, of which, by the favour of the Rev. Mr. HORNSBY, I have ſeen correſpondent obſervations, I ſuppoſe the difference cannot be much leſs than 9′ weſt of Greenwich; and at the ſame time I join an account of the ſolar eclipſe of the 24th of June 1778, which may be depended upon as a very compleat obſervation, and may ſerve to aſcertain the longitude of this place.

Eclipſe of the ſun obſerved at Bath.

June 24, 1778.

	H.	M.	S.
Beginning by equated or mean time,	3	30	10,7
End, - - -	5	18	7,7

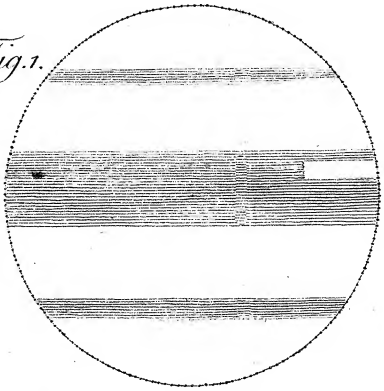
Calculations, or (as the principles on which they are founded are ſtill eſtabliſhed upon a few obſervations only, and require ſome time for mature confirmation) I would rather, if I might be allowed the expreſſion, call them calculated conjectures of the times when the remarkable dark ſpot will be ſeen near the center of the diſk of Mars.

For June, July, and Auguſt, of the year 1781.

	D.	H.	M.	S.
June	28	9	48	39
	29	10	27	10
	30	11	5	42
July	1	11	44	13
	2	12	22	32
	3	13	0	51
	4	13	39	10
	5	14	17	29
	6	14	55	46
	7	15	34	4
July	8	16	13	23
Auguſt	3	8	11	6
	4	8	49	57
	5	9	28	48
	6	10	7	39
	7	10	46	31
	8	11	25	44
	9	12	4	56
	10	12	44	8

I have the honour to be, &c.

Fig. 1.



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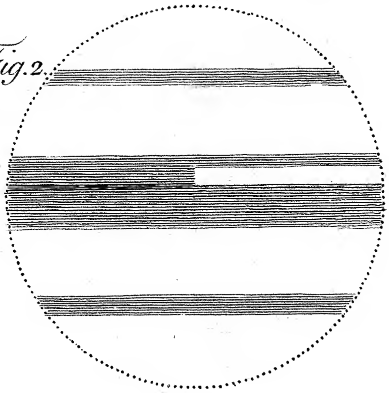

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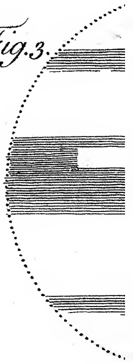

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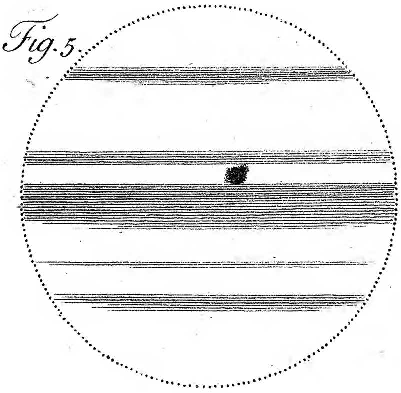

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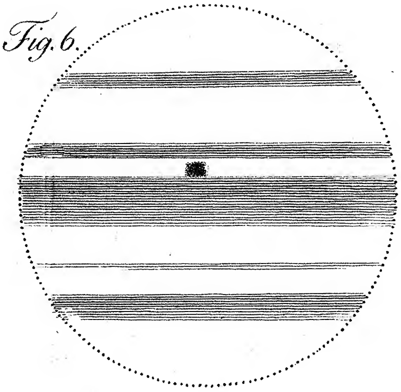

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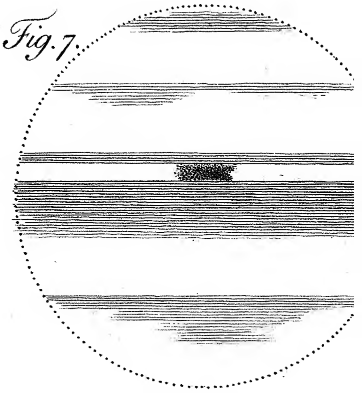

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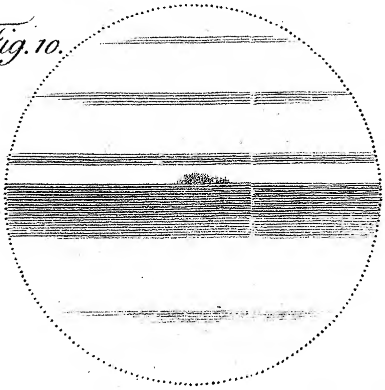

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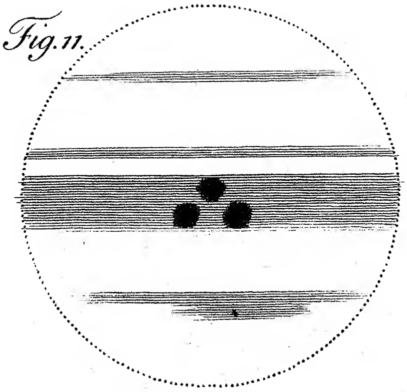

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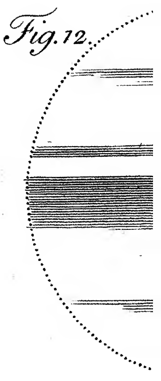

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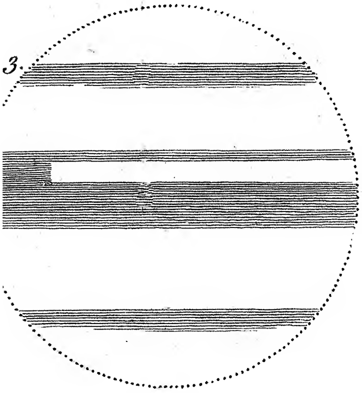

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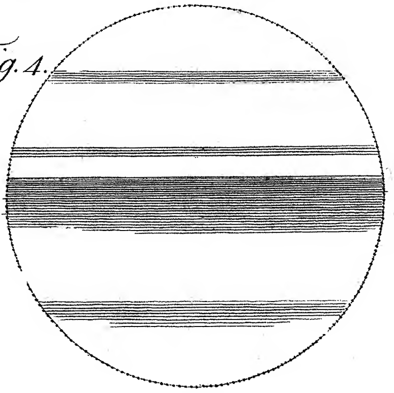

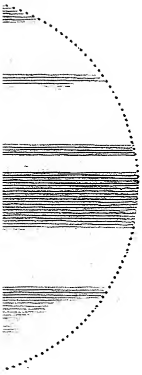

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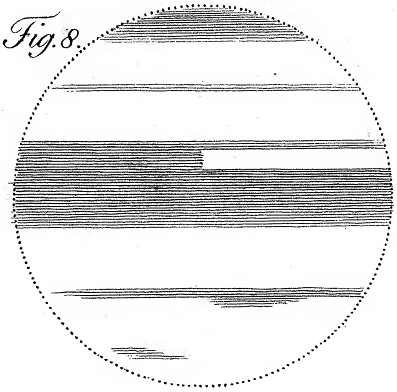

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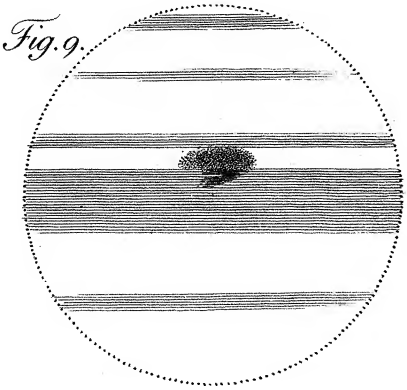

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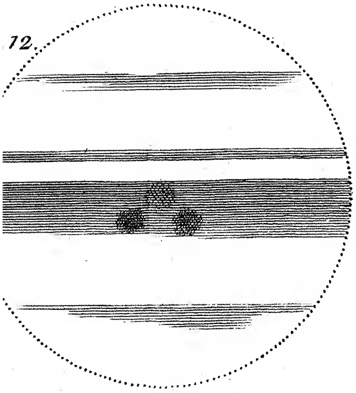

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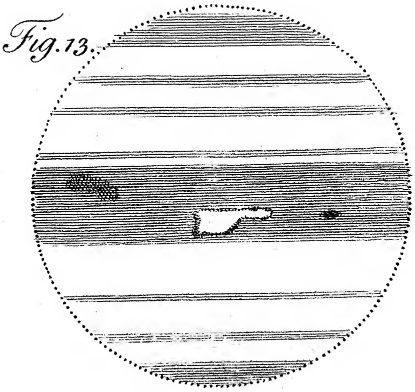

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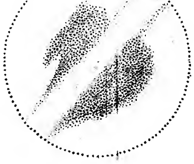

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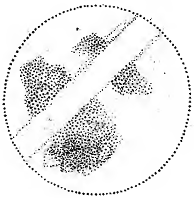

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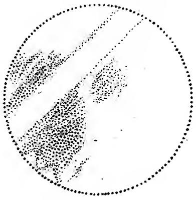

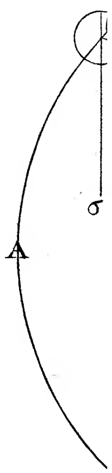

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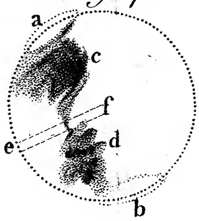

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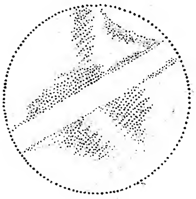

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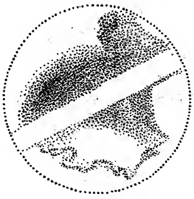

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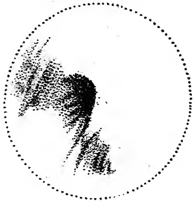

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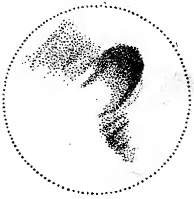

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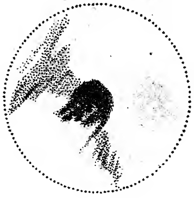

Fig

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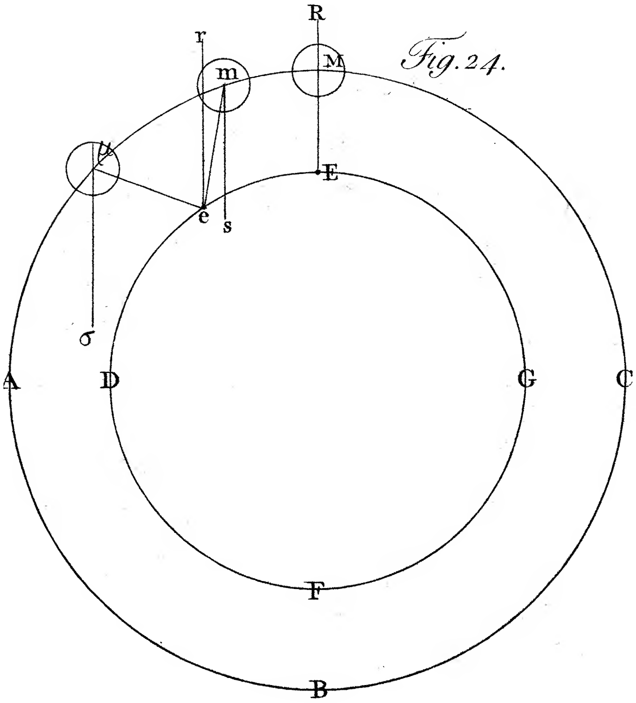
Fig. 24.



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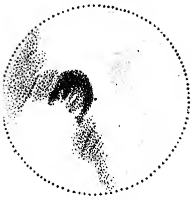

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Fig 1

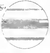

Fig 2

Fig 3

Fig 4

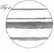

Fig 5

Fig 6

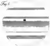

Fig 7

Fig 8

Fig 9

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Fig 12

Fig 13

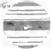

Fig. 14

Fig. 15

Fig. 16

Fig. 24

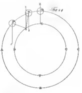

Fig. 17

Fig. 18

Fig. 19

Fig. 20

Fig. 21

Fig. 22

Fig. 23